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NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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Rocket - Borne
Topside
Sounder

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U.S. DEPARTMENT OF COMMERCE

LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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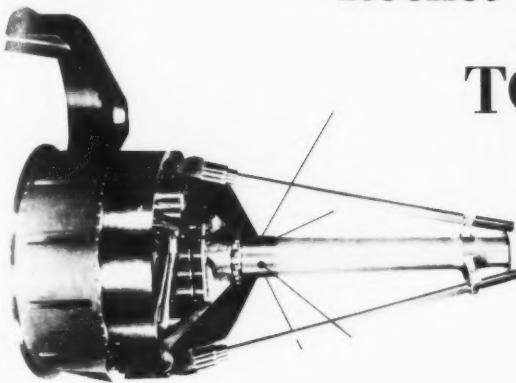
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COVER: Four-stage Javelin rocket used to carry instrumentation above the ionosphere in suborbital tests of satellite instrumentation to be used for soundings of the topside of the ionosphere. Data collected by two flights—one during a period of ionospheric calm and another when the ionosphere was disturbed—have established the soundness of the experiment and the equipment to be used in the S-48 fixed frequency topside sounding satellite which will be launched in the summer of 1962 (see p. 19).

Rocket Data Show Feasibility of

TOPSIDE SOUNDER

SATELLITE



DATA COLLECTED during two suborbital rocket firings confirm that the proposed Topside Sounder satellite should be a valuable source of new information concerning the ionosphere. The data were analyzed by the Central Radio Propagation Laboratory, at the Boulder, Colo., laboratories of NBS, which has overall planning responsibility for the satellite program under the sponsorship of the National Aeronautics and Space Administration. NBS participation in the program is directed by Robert W. Knecht, with the assistance of T. E. VanZandt and J. M. Watts.

The experimental rocket launchings pave the way for orbiting sometime next summer the S-48 Topside Sounder satellite equipped to probe the ionosphere from above. Responsibility for design and construction of the satellite—as well as the rocket payloads—is that of the Airborne Instruments Laboratory (Cutler-Hammer, Inc.). The project is under the technical guidance and management of the Goddard Space Flight Center of NASA and is part of an international cooperative program for space research.

The instrumentation to be contained in the S-48 satellite is expected to remain operational for 6 to 12 months. During this period studies will be made of such ionospheric properties as topside electron densities, ionization diffusion in the *F*-2 layer, vertical movements, tidal fluctuations, and the mechanisms that produce ionospheric storms. This information will form a part of a larger Bureau study of the structure and variability of the ionosphere over a wide range of latitudes—topics of interest because of the relationship of the ionosphere to long-distance radio communications and its rapidly growing importance to space research and technology.

Topside sounder payload—15 in. diam, 34 in. long. In orbit, the antenna poles clamped to the center column will be extended to 16 ft each at right angles to the satellite's body.

The procedure used to probe the ionosphere from above is quite similar to that used at ground-based installations. A pulsed radio wave is directed downward from the rocket (or satellite), and the reflection from the ionosphere is detected by appropriate receivers in the rocket and telemetered to recorders on the ground.

The preliminary firings served both to test the sounding equipment to be used in the satellite and to gather useful scientific information. Four-stage Javelin rockets were used to carry the instruments over 600 miles high and 1,000 miles downrange from the Wallops Island (Va.) launching site.

The first firing was made June 24, 1961, during a period of ionospheric quiet. For 14 of the 15 min that the payload was above the ionosphere, strong echoes were received of the 6 Mc/s transmission, providing considerable information concerning the topside electron densities. The echoes of an alternate 4 Mc/s pulse were weaker and persisted for a total of only about 7 min. A peak pulse power of only about 3 w was required for these soundings, as compared to the vastly greater power requirements for bottom-side experiments. A second rocket was sent aloft on October 13, 1961, to check the operation of the equipment during a period of nighttime ionospheric disturbance, and was equally successful.

In addition to the data gathered by the instruments in the rocket, 30 characteristics of the sounding equipment, such as voltages, temperatures, and accelerations, were checked and relayed to earth every second. Preliminary analysis of the data confirms that this new technique will provide information concerning the ionosphere not previously available. Already, for example, there is some evidence for the presence of ionization irregularities, probably field aligned, at altitudes of 300 to 500 miles. In the first shot (sunset), a neutral atmosphere scale-height of about 42 miles between the altitudes of about 250 and 350 miles was deduced, implying a temperature of about 1,200 °K (assuming an oxygen atmosphere), whereas in the second (near midnight), the implied temperature was closer to 800 °K.

LORAN-C CLOCK TIMING SYSTEM

A SYSTEM for controlling the time rates of widely separated clocks has been developed by G. Hefty, R. R. Doherty, R. F. Linfield, Thomas L. Davis, and Earl L. Berger of the Navigation Systems Section, at the Bureau's Boulder, Colo., Laboratories. The system utilizes radio signals from existing long-range navigation stations (Loran-C) operated by the U.S. Coast Guard, located at various points on the East Coast and compares them with an accurate master clock or frequency standard located at a central station.

First use of Loran-C to synchronize clocks to one microsecond ($1 \mu\text{sec}$) at widely separated locations was achieved on November 1, 1961, when clocks at Naval Observatory time stations at Washington, D.C., and Richmond, Fla. (near Miami), were synchronized. To insure $1 \mu\text{sec}$ accuracy the two Loran-C receivers used by the Naval Research Laboratory were temporarily brought side by side. A difference in receiver delay of $4.0 \mu\text{sec}$ was found and allowed for.

By synchronizing Loran-C with the highly accurate uniform time source maintained at the Naval Observatory in Washington, D.C., the technique is expected to provide—ultimately to large areas of the world—the precise time so necessary to the progress of space science. Scientists from four government agencies, the

The time synchronization was tested in October 1960 using the East Coast Loran-C chain, which was developed and established as an aid to navigation. The Bureau furnished engineering services to design and build Loran-C clocks and an ultra high frequency timing distribution system to demonstrate feasibility. Loran-C, as a navigation and timing system, can provide both position and time simultaneously. The new system is considered a long step forward in improving the future accuracy of tracking guided missiles and space rockets, and in the precision of data returned to tracking stations from satellites.

In the world of science, precise time—measurement of events that occur in the millionth part of a second—is a pressing need. In the majority of timing applications a problem exists in setting two or more clocks to agree with one another. The greater the requirement for agreement between the clocks and the greater the distance between them, the more difficult the problem becomes. Clocks cannot be synchronized by existing radio timing signals, other than Loran-C, to less than a millisecond at widely separated locations.

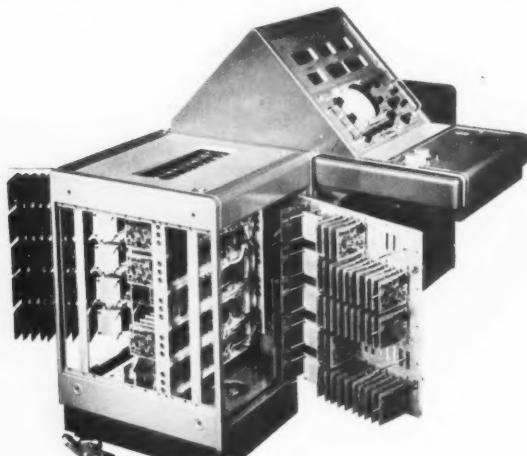
The Loran-C navigational system consists of a master transmitter at a convenient central location and other transmitters at widely separated locations which are slaved to track the master. A chain of Loran-C transmitters functions as a clock system which is internationally synchronized to better than a microsecond.

In the East Coast Loran-C chain, the master station is located at Cape Fear, N.C., and two slave stations are located at Martha's Vineyard, Mass., and Jupiter Inlet, Fla. Synchronization of this chain by the Naval Observatory with its uniform time source began in May 1961, and time synchronization is available to potential users within range of this chain.

The NBS scientists have presented a plan for inter-range timing synchronization which would provide not only a needed link between the Atlantic and Pacific missile ranges but also an excellent navigational system over the continental United States.

Additional scientific and commercial uses of a precise timing system with direct or indirect military applications are:

1. The positioning of high-altitude aircraft from the ground by using the UHF pulse technique.
2. The location of thunderstorms by precisely measuring the location of the lightning discharge.
3. The accurate position-fixing of nuclear detonations by similar means.
4. Relating with increased precision astronomical observations made at widely separated points.
5. The precise measurement of time variations on high-frequency transmissions such as WWV and diurnal variations of very low frequency transmissions such as NBA as an aid to better understanding of propagation phenomena.
6. The similar measurement on forward scatter and other types of communication systems.



The heart of the Loran-C system. Panel immediately above oscilloscope contains a 15-digit visual display covering one microsecond to hundreds of days.

Coast Guard, the National Bureau of Standards, Naval Observatory, and Naval Research Laboratory, are co-operating in developing techniques and instrumentation for obtaining precise time from Loran-C.

The early work at Boulder was sponsored by the Ground Electronics Engineering and Installation Agency of the Air Force. Additional studies on propagation are being sponsored by the Coast Guard and Naval Observatory.

1. The surveying of offshore islands and remote areas.

2. The investigation of Loran-C sky waves to give a better understanding of low-frequency ionospheric conditions.

3. Providing precise time from a single Loran-C clock, which could be made economically feasible for

a variety of users in industry and research by the application of VHF or UHF distribution systems. A relatively inexpensive receiver could be used by those located within range of the distribution system. Existing facilities such as TV transmitters could be used for this purpose.

TWO TENSILE CRYOSTATS DEVELOPED

TWO TENSILE CRYOSTATS, capable of making tests at temperatures as low as 4.2 °K. have been developed by the Cryogenic Engineering Laboratory of the Bureau's Boulder, Colo., Laboratories. The first of these devices, designed by R. M. McClintock and K. A. Warren, is capable of sustaining tensile forces up to 5,000 lbs.¹ The second, designed by R. P. Reed, has a load capacity in excess of 10,000 lbs.² The two cryostats differ not only in capacity, but in construction and operation as well. Both offer the advantages of simplicity, safety, and low consumption of liquefied gas.

The rapid growth of cryogenic engineering has increased the need for information concerning the properties of materials at low temperature. This is true not only of the fluids normally used to achieve low temperatures, but of the many materials which may be used in low-temperature installations. Of special interest is the effect of extreme cold on metals—a factor to be considered in the design of facilities for producing, transporting, and storing liquefied gases.

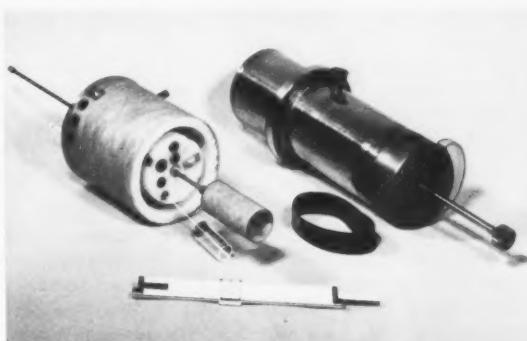
5,000-Pound Device

The cryostat having a capacity of 5,000 lbs. is used with standard tensile equipment. The tension linkage extends completely through a stainless steel Dewar and the specimen is submerged in liquid cryogen during low-temperature runs. The major modification of the equipment is the extension of the tension linkage through the vacuum space between the walls at the bottom of the Dewar. Force is transmitted across the vacuum space through a stack of metal washers, this arrangement having been found to result in less heat flow than a solid rod of the same dimensions. To further reduce heat flow into the bottom of the cryostat, the region where the linkage passes through the bottom of the outer shell of the cryostat can be surrounded with liquid nitrogen. A stainless steel bellows is welded to the bottom of the inner shell to permit specimen alignment with the universal-type linkage joint enclosed within the vacuum space and to allow for thermal contraction.

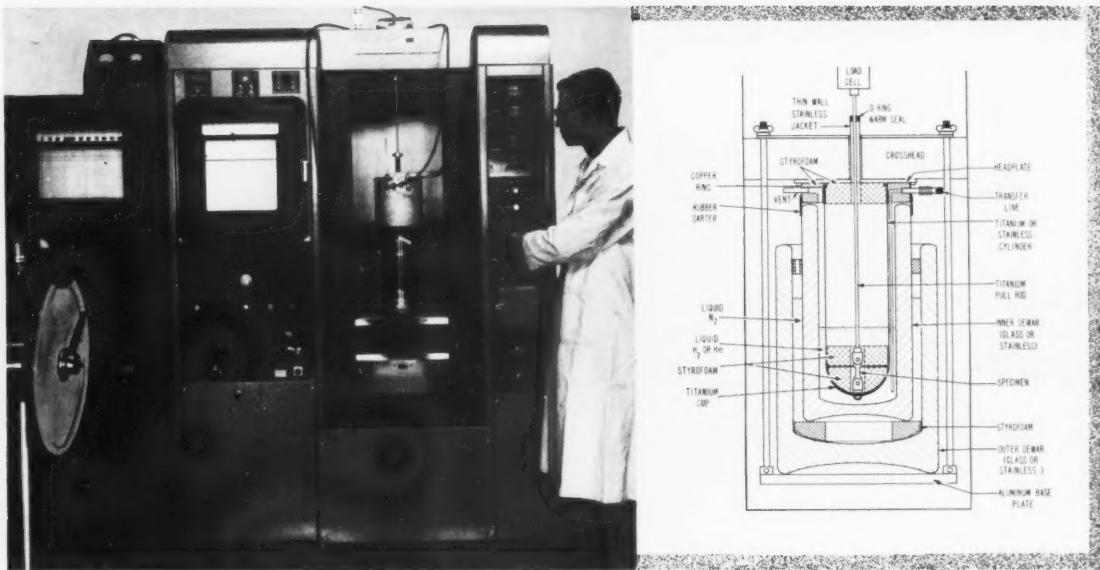
The top of the flask is closed during runs by a rigid foamed polystyrene cover which extends about 6 in. into the cryostat and which surrounds the outer walls to the same depth. A gastight seal is formed

between the lower end of the cover and a ring soldered around the outside of the cryostat by means of a thin rubber sleeve. A tube for filling and emptying the cryostat runs down through the cover. The transfer line extends down through this tube during filling and is removed and the hole corked during runs to reduce heat flow. A fluid-level float, various electrical leads, and the upper tension rod also pass through gastight seals in the cover. There is a depression in the cover which may be filled with liquid nitrogen to further reduce heat flow into the cryostat during helium runs.

When determinations are to be made at the temperature of a particular liquid, the cryostat is filled with the liquid to cover the specimen. The cryostat is precooled with liquid nitrogen prior to a helium run. When tests are to be made at temperatures intermediate to the boiling points of various liquids, an open-bottom plastic gas chamber is attached to the upper tension rod to surround the specimen; when the cryostat is filled with liquid, the sample remains in a gaseous atmosphere. Heat is then supplied to the specimen by small electric heaters on the upper and



Tensile cryostat in which the tension linkage extends through a metal Dewar. At left is the foamed polystyrene cover, with the upper tension linkage (center of cover) and liquid-level float running through it. The metal Dewar is at right, showing lower tension linkage, liquid nitrogen reservoir, and vacuum fitting. The rubber sleeve is used to make the junction between top and bottom gastight.



Right: K. A. Warren performs a tension test with the tensile cryostat having a load limit of 5,000 lb. **Left:** Tensile cryostat having a 10,000-lb. load capacity. Stress is applied to the specimen by moving the crosshead downwards, the force being transmitted through the cylinder-cup arrangement.

lower specimen holders, and the desired temperature, as measured by thermocouples attached to the specimen, is maintained by automatic or manual control of the autotransformers used to supply current to the heaters.

The liquid consumption of this cryostat is, when using hydrogen, about $2\frac{1}{2}$ liters, which will cover the sample for $2\frac{1}{2}$ hr. Three liters of liquid helium are required to cover the sample for 20 min when the nitrogen reservoirs are filled. Insulation is provided by the evacuated space between the walls of the cryostat, in preference to multiple layer insulation that would take at least 24 hr to reach thermal equilibrium. A charcoal getter is incorporated within the vacuum space to maintain the desired vacuum for several months without repumping.

10,000-Pound Device

In the second cryostat the tension apparatus extends into—but not through—the Dewar. This feature allows glass Dewars to be used, as no strain is put upon the container itself. The tensile load is applied in such a manner as to eliminate the need for low-temperature seals—in fact, only one room-temperature O-ring seal is needed.

Specimens to be tested are suspended within the Dewar from a titanium pull rod, the upper end of which is attached to a load cell. The lower end of the specimen is attached to a holder which passes through, and is bolted to, a hemispherical cup. The top of the cup is attached to a cylinder, which in turn is attached to a

headplate. The headplate is pressed downward to apply a load to the specimen, the force being transmitted through the cylinder and cup to the sample.

The cylinder-cup arrangement is surrounded by a metal Dewar containing liquid hydrogen or a glass Dewar containing liquid helium. A second Dewar of liquid nitrogen is placed around the inner flask when helium is used, or during long runs with hydrogen. Styrofoam blocks, loosely surrounding the specimen, are used during helium runs to conserve liquid by taking up space. The inner Dewar is supported on styrofoam spacers in the bottom of the outer Dewar, the latter being held securely in place by a lower plate or by pin fittings. The inner flask is sealed from the atmosphere by a rubber sleeve which is clamped to it and to a copper ring just above the top of the Dewar. When glass Dewars are used, slits in the silvered surfaces permit visual determination of the liquid level; with metal Dewars, a carbon probe is used.

The liquid consumption of this cryostat is also quite low. Three to seven liters of helium will provide a test period of 2 hr, and 2 to 5 liters of hydrogen can be used for tests lasting 4 hr. Runs at room temperature, and at intermediate temperatures using boiling liquids or various slurries, can be performed quickly and easily.

¹ For further details, see Tensile cryostat for the temperature range 4 to 300°K, by R. M. McClintock and K. A. Warren, *Materials Research & Stand.* 1, 95 (Feb. 1961).

² A cryostat for tensile tests in the temperature range 300 to 4°K, by R. P. Reed, talk presented at the 1961 Cryogenic Engineering Conference, Ann Arbor, Mich.

Study of the Mechanism of STRESS-CORROSION CRACKING

RECENTLY, H. L. Logan of the Bureau's corrosion laboratory, in a program jointly sponsored by the Corrosion Research Council and the Bureau, investigated the "incubation period" before stress-corrosion cracking occurs¹ in magnesium alloy specimens. This phenomenon was observed in an earlier study in which specimens tested at very high strain rates failed by cracking in 2.5 min² with approximately 40 sec elapsing before cracking started. The present study was undertaken to find an explanation for this delayed reaction, and also to investigate the crystallographic planes on which cracking was initiated.

Over a period of years stress-corrosion cracking has been an important source of trouble in many metals. A clearer understanding of the mechanism of stress-corrosion cracking has long been sought and basic research in this field is therefore necessary if the entire mechanism is to be understood. Stress-corrosion cracking of magnesium alloys has not been a problem; however, because of the ease with which stress-corrosion cracking in these materials can be produced in the laboratory, they offer ideal materials for a mechanistic study.

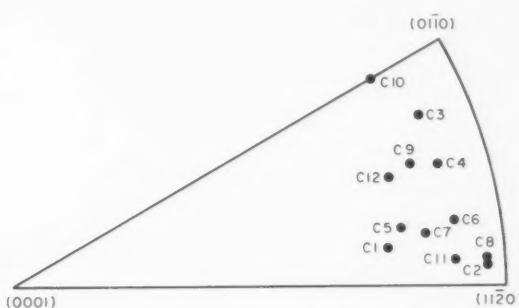
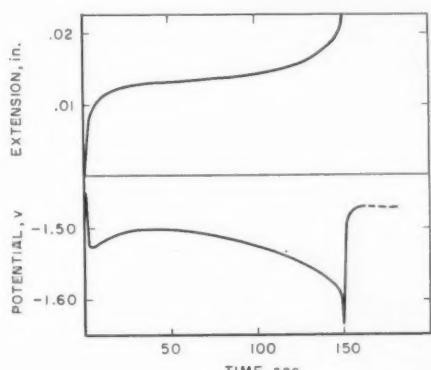
In the present study, three different types of specimens were used. The first two—sheet specimens having a 1/2-in. reduced section, machined from 1/16- and 1/8-in. thick material, and notched specimens machined from 1/2-in. diameter extruded rod—were employed in investigating the incubation period of stress-corrosion cracking. The third type—specimens made from the extruded rod with 2-in. long reduced sections having a square cross section 1/4 in. on a side—was used in locating the crystallographic planes of crack initiation. A heat treatment was given to this last group to induce grain growth and produce grains large enough so that

their orientations could be determined by conventional back-reflection X-ray techniques.

Specimens were placed in suitable cells to which the corrodent (35 g NaCl and 20 g K₂CrO₇/liter) was added and they were subsequently stressed in direct tension by means of lever systems. The resulting strain or extension was followed either manually using a dial gage reading to 1/10,000 in., or it was recorded electrically using a suitable transducer. Concurrently the electrochemical solution potentials of the specimens were determined with reference to a calomel electrode of the saturated potassium chloride type. The extension and potential could be recorded simultaneously, as functions of the time, on a two-channel oscilloscope.

An idealized curve derived from an analysis of the strain in a number of specimens showed that while most of the extension occurred on initial loading, the specimen continued to extend at a decreasing rate for 40 to 50 sec. With the initiation of stress-corrosion cracking at this time, the extension rate increased and failure occurred after a total exposure period of about 150 sec.

From simultaneously obtained data for the electrochemical solution potentials of the specimens, another curve was derived. This curve showed that on initial loading, the potential changed about 90 mv in an anodic or corrosive direction, and then over a period of from 40 to 50 sec it slowly reversed about 10 mv in a cathodic or noncorrosive direction. When stress-corrosion cracking started, the potential changed, and again increased in the anodic direction until the specimen failed. Upon failure, the potential reversed direction very abruptly, probably within 1 sec, and became only 20 mv more anodic than it was before stress was applied.



Above, left: Idealized extension-time and potential-time curves obtained simultaneously in a recent study of stress-corrosion cracking. At very high strain rates, specimens of a magnesium alloy failed in about 150 sec. Right: Stereographic triangle showing the poles of the planes on which stress-corrosion cracks were initiated. In every case, these planes made large angles with the basal (0001) plane.

These curves suggest the idea that with the application of stress the grains most favorably oriented for slip were initially deformed and hardened by cold work to resist further deformation. Protective oxide films on their surfaces, destroyed in the initial deformation, were repaired. The increase in potential in the anodic direction on initial loading was due to the rupturing of the protective film on these grains, and similarly, the decrease in potential, noted during the ensuing 40 to 50 sec, occurred as a result of film repair. Stresses concentrated in relatively more resistant crystals then deformed very limited areas of the specimen surface, during subsequent extension, but at a rate which prevented the film from re-forming. Cracking started at these film-free areas by an electrochemical process and the cracks increased in depth until the specimen fractured. As a consequence of continuous exposure of bare metal at the tips of the cracks, specimen potentials increased. The sudden decrease in potential immediately after fracture indicated that a protective film was formed very rapidly on the surface of the bare metal exposed by the fracture.

Extension rates and potentials were not obtained for the square-section specimens used to determine the crystallographic planes of stress-corrosion cracks, and the stresses were removed after cracks had developed but before final fracture in these specimens. Data obtained in this part of the work indicate that crystals in which cracking occurred were generally less favorably oriented for slip than were those crystals in which no cracks developed, i.e., cracking occurred in crystals that resisted the early deformation. The cracks produced in these specimens were approximately normal to the stress axis; they made large angles with the basal plane; and they usually occurred on high-index crystallographic planes.

¹ For further technical details, see Stress-corrosion cracking of the AZ31B magnesium alloy, by Hugh L. Logan, *J. Research NBS (Eng. and Instr.)* **65C**, 165 (1961).

² Mechanism of stress-corrosion cracking in the AZ31B magnesium alloy, by Hugh L. Logan, *J. Research NBS* **60**, 503 (1958) RP2919; also, *NBS Tech. News Bull.* **43**, 63 (1959).

NBS and Navy Announce Change In Standard Frequency Broadcasts

A CHANGE in the broadcast of standard frequency transmissions has been jointly announced by the Bureau and the U.S. Naval Observatory, the two Federal agencies that coordinate transmissions of time and standard frequency. At zero hours Greenwich Mean Time of January 1, 1962 (7 P.M. E.S.T. December 31, 1961) the standard frequencies transmitted were made higher by 2 parts in 1 billion. This is 2 ten-millionths of 1 percent. The change is too small to be detected by ordinary radio receivers; that is, the nominal frequencies broadcast are the same, but it is significant to those using specialized equipment in precise scientific work.

The change was necessitated by irregular variations in the speed of rotation of the earth. Astronomical observations made at the U.S. Naval Observatory have shown that the earth was rotating at a successively slower speed each year from 1955 to 1958 and that since then the earth has been rotating at a faster speed each year. The cause of this irregular variation is not known.

Time pulses and carrier frequencies of the standard broadcasts are locked together. The frequencies transmitted are maintained constant each year with respect to Atomic Time, but are offset from Atomic Time by a specified amount to provide time signals which correspond closely to time as based on the rotation of the earth. The frequencies transmitted in 1962 will be 13 parts in 1 billion lower than that of the cesium

atomic clock, whose frequency is 9,192,631,770 c/s. If such offsets were not maintained, it would be necessary to make frequent step adjustments during the year in the time signals broadcast.

U.S. stations whose frequencies were changed are WWV, Beltsville, Md.; WWVH, Hawaii; WWVL and WWVB, Boulder, Colo.; NBA, Canal Zone; NAA, Cutler, Maine; NPG, Jim Creek, Wash.; and NPM, Hawaii. The transmissions of the East Coast Loran-C radio navigation system operated by the U.S. Coast Guard were also changed in frequency. The Loran-C transmitters are located at Cape Fear, N.C.; Martha's Vineyard, Mass.; and Jupiter Inlet, Fla.

The transmissions of time and frequency of the United States are coordinated with those of Argentina, Australia, Canada, Japan, South Africa, Switzerland, and the United Kingdom. This coordination began in 1959. The standard frequency and time transmissions of these countries also changed on January 1, 1962.

The need for high precision in scientific measurements, in satellite tracking, in radio communication, and in navigation has made it necessary that frequency be provided with very high precision and that transmissions be coordinated. Transmissions of frequency are maintained constant to 1 part in 10 billion. This amount corresponds to 3 thousandths of a second per year, which is an appreciable quantity in many scientific applications.

Corrosion Rates Measured Electrically In an Underground Environment

A LABORATORY METHOD often employed to find the corrosion rates of ferrous metals exposed to soils and to salt water solutions may also be used to determine such rates in an underground environment, according to a recent Bureau study. By this method the corrosion rate, based on cumulative weight loss, is calculated from polarization measurements. Values for weight loss thus derived in the present study for a steel and an aluminum specimen showed good agreement with actual weight loss determined after the exposure period. These results indicate that the technique has practical field applications for estimating corrosion rates and for measuring soil corrosivity.¹

To obtain polarization measurements, cathodic and anodic currents are periodically applied in increasing amounts to a corroding specimen. Weight loss over a specific time interval is calculated from the current values that coincide with changes-in-slope or breaks in the respective polarization curves (current versus potential). These values indicate the currents necessary to stop local-action corrosion. W. J. Schwerdtfeger of the Bureau's corrosion laboratory undertook the present experiment to evaluate the method for underground studies, and to correlate climatic variations with corrosion data.

A steel specimen of low carbon content and an aluminum specimen of high purity, both tubular in shape, were chosen for the experiment. They were 30.5 cm (12 in.) long, 4.75 cm (1.87 in.) in diameter, and their ends were sealed with rubber caps, leaving 372 cm² (0.4 ft²) of outer surface for exposure to the soil. They were buried outside the corrosion laboratory, spaced 0.914 m (3 ft) apart in a vertical position in 0.762 m (30 in.) deep holes. An auxiliary electrode that served either as an anode or a cathode during the measurements was buried 6.10 m (20 ft) away. Rubber-insulated stranded copper wires attached to this electrode and to the specimens were connected to a two-pen recorder installed in the laboratory for recording the polarization data.

When measurements were to be made, a reference electrode similarly wired was placed on the surface of the ground about 0.914 m (3 ft) from the specimens, between them and the auxiliary electrode. A bridge circuit was used in conjunction with the recorder to balance out the IR drop through the soil between the specimen and the reference electrode, resulting from the applied current.

In the experiment, measurements were made 40 times over a 16-month exposure period. Data obtained on the recorder charts were re-plotted to show the currents on a logarithmic scale. The currents at which significant changes in slope occurred were used to calculate the instantaneous rates of corrosion. Calculated and actual weight losses determined at the end of the exposure period were 18,027 mg and 19,055 mg respectively for the steel specimen, and 61 mg and 109 mg respectively for the aluminum specimen. These calculated weight losses were considered quite significant. Weather data during the exposure period were obtained from the U.S. Weather Bureau, and correlated with the measurements.

The calculated corrosion rate for the steel specimen fluctuated considerably during the first two months of exposure following heavy rainfall between dry periods. The corrosion rate of the aluminum was less affected by weather variations. The data showed that the corrosion rate of the aluminum decreased about 30-fold and that of the steel about 8-fold during the exposure period. It must be pointed out that the amounts of corrosion and corrosion rates found in this study do not indicate the relative merits of the two metals, since only one soil of comparatively high resistivity (7,500 ohm-cm) was used as the corrosive medium. Completely different results might be obtained in another environment.

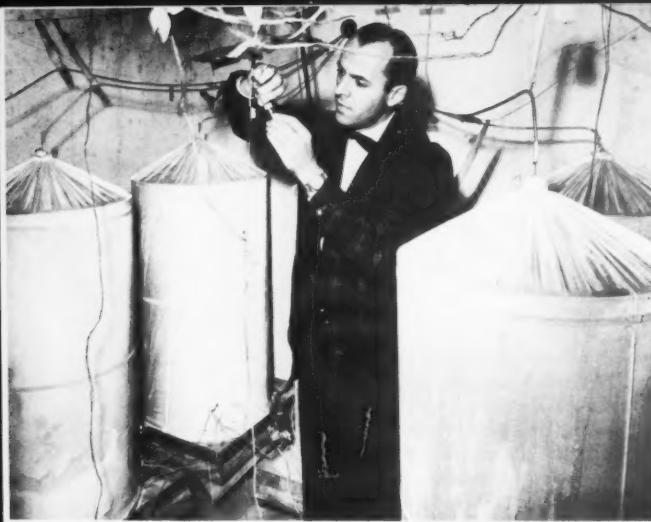
Cathodic polarization data obtained for both specimens during the study fitted quite well a logarithmic relationship between the cathodic current at the break in the curve and the polarization rate ($\Delta V/\Delta I$). This relationship may be useful in anticipating corrosion rates when changes-in-slope are not well defined. Hence, these data and data obtained in a previous study² were used to develop an empirical equation to relate the controlling polarization current at the break in the curve to the polarization rate.

¹ For further technical details, see A study by polarization techniques of the corrosion rates of aluminum and steel underground for sixteen months, by W. J. Schwerdtfeger, *J. Research NBS* **65C** (Eng. and Instr.) 271 (1961).

² Coatings formed on steel by cathodic protection and their evaluation by polarization measurements, by W. J. Schwerdtfeger and Raul J. Manuele, *ibid.*, 171; also *NBS Tech. News Bull.* **45**, 156 (1961).

Errata for NBS Handbook 77—Precision Measurement and Calibration

In the first printing of NBS Handbook 77—Volume I, Electricity and Electronics, issued February 1, 1961, two pages of illustrations (216a/274 and 316/6) were erroneously omitted. These two pages will be sent upon request to: National Bureau of Standards, Publications Section, Washington 25, D.C.



F. J. J. Drapeau inspects a humidity-sensing element used for evaluating conditions in an experimental underground shelter.

A FAMILY-SIZE underground fallout shelter at the Bureau, with six simulated "occupants," has served for a study of ventilation, heat, humidity, and air-conditioning problems connected with such shelters. The study, sponsored by the Office of Civil Defense, was conducted by P. R. Achenbach, F. J. J. Drapeau, and C. W. Phillips of the NBS mechanical systems laboratory.¹

The "occupants'" appearance was such that they could hardly be confused with humans. However, four of the six had the heat-emission characteristics of an average seated and quiet adult. These were known as the 400-Btu/hr (120 w) occupants, since they were designed to release this quantity of heat, the average for a sedentary adult. A fifth, known as the 600-Btu/hr (180 w) occupant, was so designated because he was presumed to be exerting himself, cranking the blower of the ventilation system for the shelter. The sixth, a 200-Btu/hr (60 w) "occupant," was presumed to be a child giving out heat at half the adult rate.

Various types of fallout shelters have been constructed elsewhere and tested for effectiveness against radiation fallout. However, the primary purpose of the NBS study was to obtain engineering data on the environmental factors that affect the habitability of a shelter, and the comfort and well-being of its occupants. With this objective, observations were made at regular time intervals of temperature, humidity, ventilation rate, and heat exchange during periods of occupancy up to 14 days.

Data were collected on moisture conditions inside the shelter and the effect on the interior of the above-ground daily temperature cycle. Data were collected also on the amount of air needed under different conditions to hold to bearable levels the heat and humidity produced by six typical occupants. In addition, information was gathered to permit further analysis of the effect of soil characteristics, moisture content of the soil, thickness of concrete walls, outside temperature

Simulated "Occupants" of Family-Sized Shelters

and humidity, latitude of the site, and quantity of ventilating air on the moisture and thermal conditions in shelters of various sizes.

Description of "Occupants"

Each "occupant," made of 24-gage galvanized steel, consisted of a cylindrical section 22 in. in diameter and 38 $\frac{1}{8}$ in. high, topped by a conical "dome" 5 $\frac{1}{2}$ in. high. An aluminum liner reduced radiation from the heat source to the outer cylinder and increased internal convection. An aluminum-foil radiation shield was installed underneath each dome.

A 200-w light bulb at reduced voltage served as the heat source in each of four 400-Btu/hr occupants and the one 200-Btu/hr occupant, while a 660-w cone-shaped resistance heater at reduced voltage served the sixth, the 600-Btu/hr occupant.

A smooth, closely-woven fabric with long fibers spread water over the exterior surface of each occupant for evaporation. A snug-fitting wrapper of the fabric was fitted over the cylindrical portion of each and was gathered into folds over the dome and sewed together at the top. Water was dripped into the gathered fabric at the top of the dome and spread over the exterior surface by wick action. Some of the air rising from these fabric surfaces probably had a moisture content comparable to that of the exhaled breath of a human being.

Each occupant was supported in a pan, 2 ft square and 2 in. deep, for collection of excess water. Pans and occupants were mounted on cinder blocks, with a clearance of about 10 in. between the floor and the bottom of the pan.

For purposes of temperature measurement, five thermocouples were soldered to the cylindrical walls of each occupant; and one additional thermocouple was attached to each dome 3 in. from the top.

Construction of Shelter

The shelter to house the occupants over the test period was constructed on a well-drained site on the NBS grounds, in accordance with plans in Bulletin MP-15 of the Office of Civil Defense.

In excavating for the shelter, a pit 13 $\frac{1}{2}$ ft wide, 16 ft long, and 7 ft deep was dug. The 16-ft central axis was oriented about 20 deg west of magnetic north. Exterior dimensions were 12 ft long by 9 $\frac{1}{3}$ ft wide, by 7 $\frac{1}{2}$ ft high, not including the hatch. The interior was 10 $\frac{2}{3}$ ft long, 8 ft wide, and 6 $\frac{1}{2}$ ft high. The hatchway on the north side was 2 ft wide and the shielding wall was 8 in. thick, leaving a main room 8 ft square. About

"Counts" Aid Study of Mini-Size Underground Fallout Shelter

12½ cu yd of concrete were used for the structure, corresponding to a total weight of about 49,600 lb.

Hot asphalt was applied to the exterior of the walls and roof as a moisture barrier. Backfill was placed in layers about 18 in. thick and tamped thoroughly to obtain successive layers about 12 in. thick and of the proper density. Layers of dry ice, placed between the layers of backfill, served to remove excess heat absorbed by the excavated earth during storage on the ground surface and thus shortened the preconditioning time of the shelter.

The entire area was graded and covered with 225 sq yd of sod. The top of the embankment was leveled and graded horizontally, so that the surface line of the sod was 3 in. below the top edge of the hatch, thus providing an earth cover 2½ ft thick over the shelter roof.

Apparatus Used

The test apparatus used for this study included the following:

(1) A thermocouple system for measuring the temperature of the concrete in the walls of the shelter, in the adjacent earth to a distance of 4 ft from the walls, and in the undisturbed earth at a greater distance.

(2) A specially designed air washer for conditioning the ventilating air to the selected dry-bulb and dew-point temperatures, and for regulating the flow of air. It consisted of a duct 12 in. square and about 4 ft long made of 16-gage galvanized steel, with four water sprays, an eliminator, and a sump at one end. The water sprays bathed the internal walls of the duct. There was enough evaporative surface to saturate the air at the water temperature. The sump collected the excess water for recirculation, and incorporated a float-controlled water feed for makeup. Air from a nearby instrument building was forced through the washer, and then successively through an electric re heater, a measuring orifice, the supply line to the shelter, and the shelter itself by a centrifugal blower. The air flow rate was controlled manually at the blower outlet by an adjustable damper. The direction of heat exchange between supply line and ambient air depended on whether the outdoor temperature was above or below the air temperature in the supply line. For summer tests, the air-supply line was well insulated and covered with an aluminum wrapper to reduce the heat transfer and prevent entry of moisture into the insulation. For a winter test a part of the line was jacketed with crushed ice to maintain the desired temperature.

(3) Temperature and humidity elements for measuring the condition of the air entering the shelter and at various stations inside the shelter. An electric heater at the washer outlet was controlled by a temperature-sens-

ing element in the supply line at the shelter entrance. Meanwhile, the chilled water temperature in the air washer was adjusted to maintain the dew-point temperature at this same location at 69 °F for the summer tests and 33 °F for the winter test.

(4) A water-feeding system for the simulated occupants consisting of six separatory funnels for gradual feeding of measured amounts of water through separate plastic tubes to the simulated occupants for evaporation on their surfaces.

(5) Heat flowmeters to measure the rate of heat transmission at the interior surfaces of the shelter.

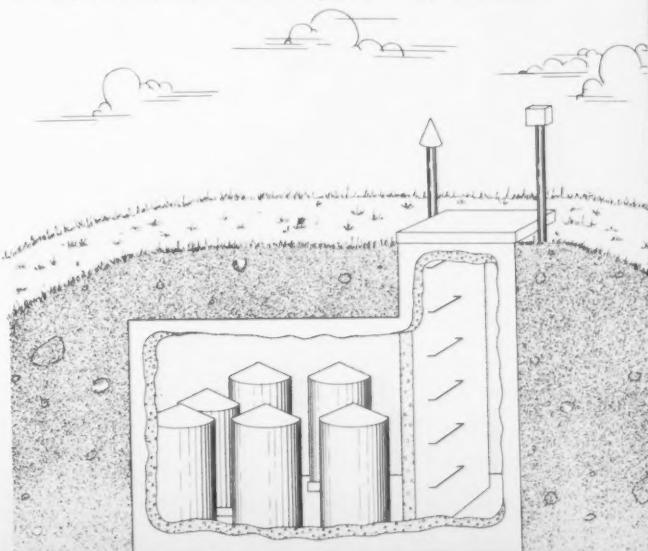
(6) Various instruments for measuring temperature, humidity, air flow rate, electrical energy consumption, heat-flow rate, and solar radiation.

Test Procedures

Five tests of the shelter were made with variations in duration, ventilation rate, ventilating air conditions, and occupancy. Four took place when the earth temperature was near the summer maximum and one near the winter minimum. (See table below.)

During the tests the latent and sensible heat outputs of the simulated occupants were controlled, first, by adjusting the total electrical energy supplied to the electric heat source inside each one, and secondly, by adjusting the amount of water dripped on the fabric covering the "occupant." On the assumption that all of the water would be evaporated, the remainder of the heat would be transferred as sensible heat and the pro-

Cutaway view of the small underground fallout shelter.



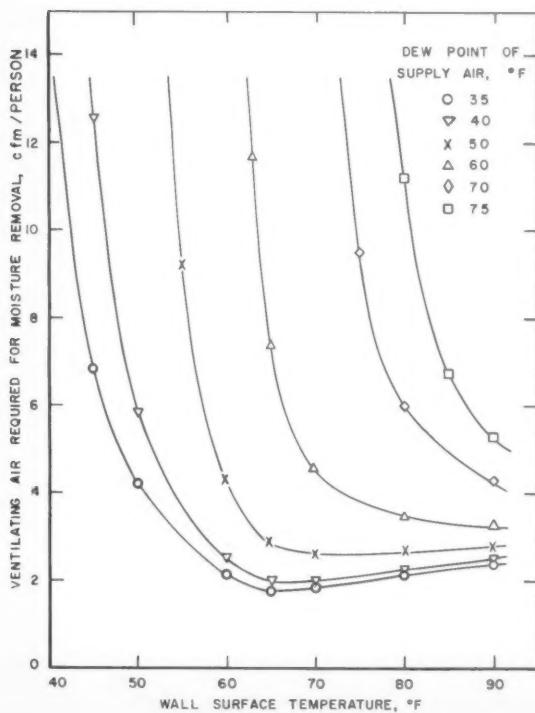
Schedule of test conditions

Test number	Duration of test	Ventilating air supply			Number of simulated occupants	Approx. internal heat input
		Flow rate	Average dry-bulb temp.	Dew-point temp.		
1	7 Days	cfm	°F	°F	0	Btu/hr 110
2	7	42	85	69	6	2,500
3	14	42	85	69	6	2,500
4	14	18	85	69	6	2,500
5	14	18	35	33	6	2,500

portions of sensible and latent heat emission would attain the desired values. The "domes" operated at temperatures ranging from 94 to 97 °F.

At the time selected for the beginning of each test, usually between 9 and 11 a.m., the conditioned air supply was turned on, the electric heaters in the simulated occupants were energized, and water was fed to each occupant in specified quantities.

At 2-hr intervals, the temperature was taken at six stations on each occupant, and various temperature and humidity readings were taken in and around the shelter. Other measurements included the total water fed to each occupant at regular intervals, electric energy consumption of the occupants and the electric light bulbs, and temperature of water dripped on simulated occupant No. 1.



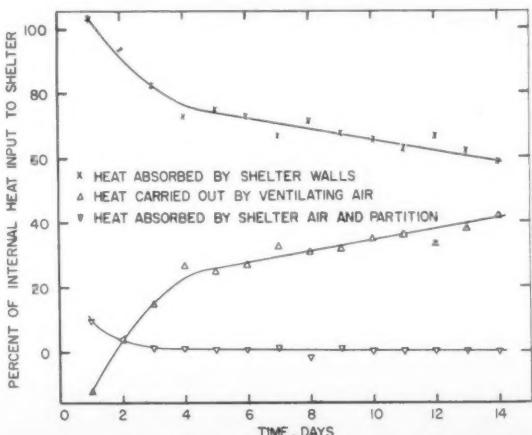
Temperature and Humidity

High relative humidities prevailed in the shelter during both summer and winter tests. These high readings were accounted for in the summer by the high dew point of the ventilating air, the water vapor released by the "occupants," and the small temperature differences between the air and wall surfaces. The conclusion was reached that moisture and condensation control would be a major problem in small shelters, since high humidity and condensation on the walls and on the ceiling would be prevalent in most seasons of the year. The ceiling was considered to be the most critical surface with respect to condensation because the water would drip on everything and everybody in the shelter.

To meet this problem, the ceiling might be insulated or lined to prevent condensation, leaving the walls and floor as condensing surfaces from which drainage could be more readily controlled. Also, film-type movement of the condensate from the ceiling to the side walls would be promoted by doming or sloping the ceiling surface downward to the side walls and treating the ceiling surface with a wetting agent. Still another moisture-control method would be to store a sufficient quantity of a drying agent or desiccant in the shelter to absorb excess moisture during occupancy.

It was learned that short-term variations in weather conditions probably had little effect on heat transfer below midheight of the shelter, that is, about 6 ft below the surface of the earth. Five days elapsed before the effect of a sustained change in the weather was observed at midheight of the shelter. The daily temperature cycle was not felt much beyond a depth of 1 ft in the

Data were obtained on the heat transferred from 6 simulated occupants installed in the shelter. Graph, left, shows the heat transfer to shelter walls, to shelter air and partition, and to ventilating air as a percent of the internal heat input. Below: Calculated values for the relations of the temperature of the wall surface in a small underground fallout shelter to the dew point temperature of the supply air and to the amount of ventilating air needed to prevent condensation.



earth, which meant that the effects of this cycle were nullified before reaching as far down as the roof of the shelter.

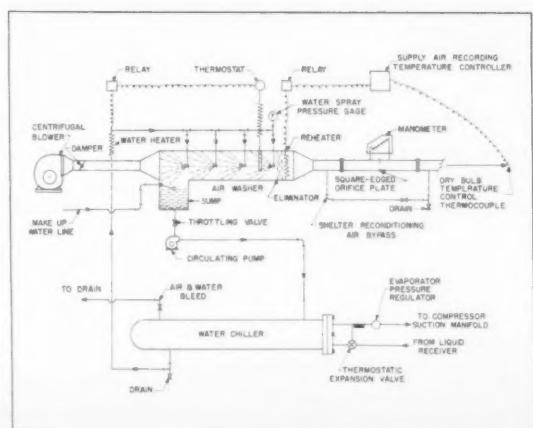
The conclusion was reached that a longer subterranean duct to condition the supply air would be advantageous for small shelters, especially for the hottest or coldest weather. The temperature gradient in the earth is in opposite directions at the warmest and coldest seasons. Thus, if the supply air were introduced through a duct installed beneath the floor, the air could be cooled in the warmest weather and warmed in the coldest weather by heat exchange between the duct and the surrounding earth. Some dehumidification might also be accomplished during the summer in such a subfloor duct.

It was found that the ventilation rate required to prevent condensation was related to the wall temperatures in the shelter and the dew point of the ventilating air. In some locations and under some weather conditions a ventilation rate of 3 cubic feet per minute (cfm) per person would be adequate to control the temperature and prevent condensation, and in other conditions more ventilation would be required. A ventilation rate of 3 cfm per person was ample to provide the oxygen requirements in the shelter.

The rise of interior dry-bulb temperature during the summer tests as a result of an average heat release of about 2,500 Btu/hr by the six "occupants" and other heat sources ranged from 12 to 15 °F. This rise probably would not create unendurable conditions in a small shelter in areas where the initial earth temperature did not exceed about 73 °F.

S. H. Dole, in a paper on environmental requirements for extended occupancy of manned satellites,²

Below: Schematic and flow diagram of the air washer system used to condition the ventilating air for the experimental underground shelter. This shelter was designed to obtain engineering data on environmental factors such as temperature, humidity, ventilation, and heat transfer. **Right:** Vertical section and plan view of a prototype underground fallout shelter showing locations of the simulated occupants (simocs), air supply and exhaust lines, and some of the instrumentation.

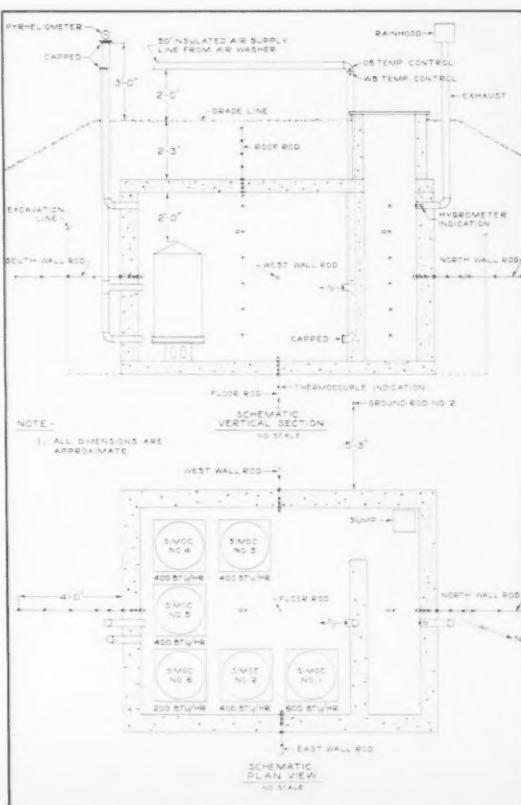


has suggested that the maximum temperature of saturated air which can be tolerated by human beings continuously for 10 days ranges from 81 to 86 °F. Other investigators^{3, 4} have stated that for saturated air, the temperature range of 88 to 90 °F is the upper limit for which man can compensate for atmospheric conditions and maintain the desired body temperature. This latter limit applies to exposures of no more than a few hours.

The effective temperature in the shelter during the 14th (last) day of the third and fourth tests was about 80 deg. For the period August 13–27, 1959, average effective temperature at the Washington National Airport was 80.3 degrees, neglecting effects of solar radiation and wind. Thus, the comfort conditions in the shelter at the end of these tests probably were no more adverse than outdoor conditions during 2 weeks of the 1959 summer season in Washington, D.C.

A number of factors could increase temperatures in the shelter. Among these are:

(1) A higher heat output by actual living occupants than was used in the study for the simulated occupants. The output in the study approximated that for sedentary adults in normal environments. However, it is not known whether mental stress in an emergency would increase the occupants' heat production.



(2) Higher earth temperatures than those in Washington at the time of the study. These could probably be partly compensated for by placing the shelter farther beneath the surface. It was found in Washington, D.C., that the earth temperature decreased about 1 degree per foot of depth about September 1 when earth temperatures were maximum. In the hottest parts of the United States it is believed that unbearably hot conditions could develop in the summer. However, simple evaporative coolers with manually operated fans could probably provide limited cooling in hot, arid climates.

The one winter test, conducted with a steady flow of supply air at 18 cu ft/min and a dry-bulb temperature of 35 °F when the earth temperatures were about at a minimum, revealed that the shelter temperatures would not reach comfortable levels in 2 weeks with an internal heat input equal to that of six sedentary adults. Steps, therefore, would need to be taken to increase comfort of shelter occupants during cold weather.

It was suggested in the study that winter comfort might be improved by using a small vented heater; wearing additional clothing; placing a curtain at the doorway of the main room to reduce the area for heat loss; draping aluminum foil over the walls to provide air spaces and to present a surface for reflection of body heat; and reducing the ventilation rate, if resulting condensation could be tolerated.

¹ For further technical information, see Environmental characteristics of a small underground fallout shelter, by P. R. Achenbach, F. J. J. Drapeau, and C. W. Phillips, *ASHRAE Journal* 4, 21 (1962).

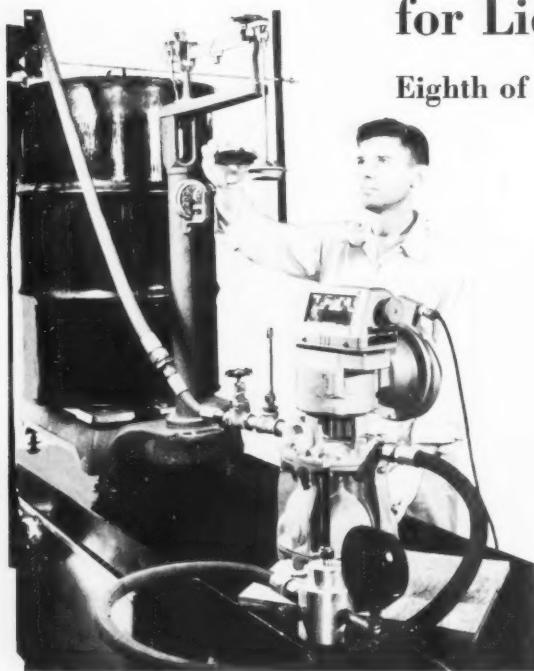
² Environmental requirements for extended occupancy of manned satellites, by S. H. Dole, *ASME Paper 59-AV-12* (1959).

³ Temperature and human life, by C. E. A. Winslow and L. P. Herrington, *Princeton Univ. Press* (1949).

⁴ Air motion, high temperature and various humidities—reactions on human beings, by W. J. McConnell, F. C. Houghton, C. P. Yaglou, *ASHVE Transactions*, Vol. 30 (1924).

Calibration of Flowmeters for Liquid Hydrocarbons

Eighth of a Series on NBS Measurement Services *



A static, weigh-type calibrator is used to calibrate a positive displacement meter equipped with an electronic pulse generator. K. R. Benson determines the net weight of hydraulic oil collected in the drum which is on a platform scale. This weight is converted to volume. The total number of pulses generated by the meter as determined by the electronic counter (*far right*) while the oil was being collected is divided by the volume to obtain the calibration factor of this meter.

ACCURATE MEASUREMENT of the flow of fuel is required in the test and adjustment of aircraft and missile engines to assure satisfactory performance in flight. The devices which measure this flow must therefore be calibrated with the greatest practical precision.

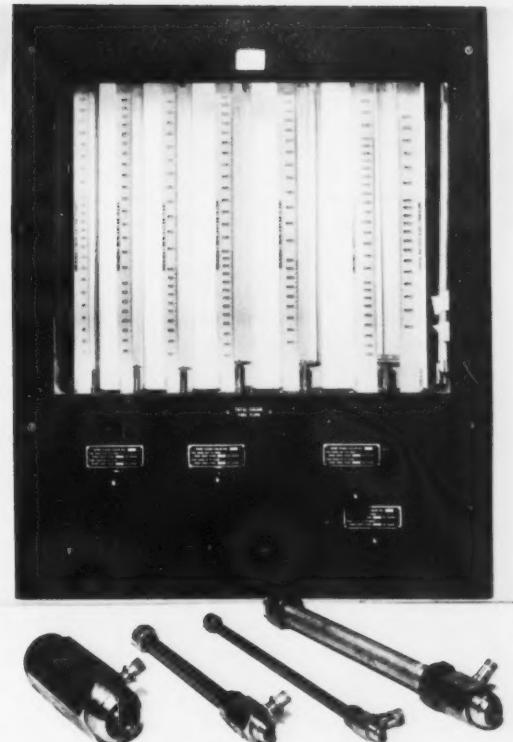
Many industrial operations in various fields, in addition to aircraft factories and Armed Service installations, maintain equipment for calibration and check of liquid flowmeters used by their activities. And it is desirable that a convenient procedure be provided to bring about agreement among all these diversified installations throughout the country.

The Bureau therefore maintains reference flowmeter calibration facilities for use with liquid hydrocarbons and provides assistance to enable other laboratories to perform their calibrations accurately. The program is sponsored by the Bureau of Naval Weapons and is directed by M. R. Shafer of the Bureau's combustion controls laboratory.

* Previous articles have been: *Calibration of Gage Blocks*, Feb. 1961; *Thermocouple Calibrations*, Mar. 1961; *Calibration of Platinum Resistance Thermometers*, Apr. 1961; *Calibration of Inductive Voltage Dividers*, May 1961; *X- and Gamma-Ray Calibration*, July 1961; *Calibration of Microphones*, Nov. 1961; and *Calibration of Optical Pyrometers*, Nov. 1961.



Above: E. R. Paul calibrates an orifice flowmeter. The tall liquid differential head manometer (left) and the mercury U-tube manometer (right) are used for measuring pressure differentials; and the electronic, counter-type timer is used in measuring the time required to collect selected weights of liquid. **Right:** Other types of meters calibrated frequently at the Bureau include the multi-tube, variable-area, float-type meter and the turbine-type flowmeters of assorted sizes with entrance flow straighteners attached to eliminate the effect of swirl on meter performance.



In addition to calibration work performed for the Navy, the Bureau during the last year has participated in accuracy evaluation programs on flowmeter calibration equipment with eight aircraft manufacturers, four service facilities, and three flowmeter manufacturers. These programs involve calibration of reference flowmeters at the Bureau for the interested activity. Generally the degree of agreement obtained was better than 0.2 percent.

Transfer References

The above problem is complicated by the fact that flowrate, the ratio of the mass or volume of flow to time, is a dynamic quantity not defined conveniently by a single certified standard such as mass or length alone. To meet this situation, the use of transfer reference flowmeters has become quite common.

In order to encourage and systematize this transfer reference activity, the Bureau operates reference flowmeter calibrators for use with liquid hydrocarbons, including aircraft fuels and lubricants. These calibrators make it possible for others to maintain traceability of their liquid flowmeter calibrators to similar calibration equipment maintained at NBS.

Generally, flowmeters can be calibrated at rates up to 200 gpm with liquid hydrocarbons having kinematic viscosities less than 10 centistokes. Liquids of higher viscosities, such as lubricating and hydraulic oils, can be handled at rates up to 30 gpm. Flowrate calibra-

tions usually come within 0.15 percent of absolute with possible exceptions at the extremes of the range. However, totalizing meters can be calibrated at rates up to about 100 gpm, to accuracies usually within 0.1 percent of absolute. The above calibrations can be performed on all types of liquid flowmeters provided the required operating pressure level does not exceed 40 psig.

Care is required in selection of transfer references if repeatability of the order of 0.1 percent or better is to be obtained. Precisions of this magnitude are attained only when all factors which influence performance are known, specified, and controlled. Entrance flow pattern, pressure level, meter orientation, and test liquid density, viscosity, and temperature are the more important factors in establishing consistent conditions which can be duplicated at different locations.

The type of transfer reference flowmeter to be calibrated is agreed on between NBS and the interested facility which supplies the meter. Types chosen up to now include turbine flowmeters, variable-area glass tube types, orifice meters, and positive displacement meters. Each of these has its own particular advantages for the rates of liquids encountered. However, no type can be counted on with complete assurance for the precision and stability desired in a perfect transfer reference for accuracies to 0.1 percent. Considerable

preliminary testing therefore is necessary to pick out the specific meters to serve as transfer references.

After calibration at the Bureau, the meters are returned to the owners with a report on results. The reference meters are then used by the other laboratory to conduct periodic checks of its own calibrators.

Normally, the reference meters are sent to NBS for recalibration in one or two years. However, recalibration is performed as requested whenever appreciable deviations occur or malfunctioning of a meter is suspected.

Calibration Methods

The flowmeter calibration equipment used by NBS with liquid hydrocarbons has been described briefly by Shafer and Ruegg.¹ Equipment now in operation includes a static weigh-type calibrator having a maximum flow capacity of 30 gpm; and a dynamic weigh-type unit, commercially available, having a maximum capacity of about 200 gpm. The accuracy of the latter unit was found to be within 0.15 percent.¹ Frequent comparisons are made between this unit and the 30-gpm calibrator. The weigh-scales of both are calibrated periodically by loading with Class C weights, and the timers are compared with the standard time signals of NBS radio station WWV.

Nearly all the reference calibration work at the Bureau is performed with MIL-F-7024A, Type II, a closely specified hydrocarbon blend used as a reference calibrating fluid for fuel metering and control components throughout the aircraft industry. This liquid has a 60/60 °F specific gravity range² of 0.765 to 0.775, and a kinematic viscosity range of 1.10 to 1.20 centistokes at 80 °F. Type II liquid is stable in that its physical properties do not change significantly because of evaporation at temperatures below 100 °F.

Calibrations also are performed with the more common lubricating and hydraulic oils. However, hydrocarbon blends with low initial boiling points and wide distillation ranges, such as gasoline, are not used. The latter are not suitable for calibration of reference meters because of rapidly changing density and viscosity due to evaporation. In special instances where a liquid similar to gasoline is required, MIL-F-7024A, Type I, a commercial grade of normal heptane, is employed. This liquid has a narrow distillation range, and its density and viscosity remain nearly constant when evaporation occurs.

The actual calibration points for the individual meters are selected through agreement between the interested facility and NBS. These points must correspond to flow rates at which the reference meters have demonstrated adequate scale resolution and good stability of calibration. Also, the selected rates should be suitable for the particular accuracy evaluation program under consideration. Approximately five different calibration points are usually chosen for each meter, and these generally cover a flow range of about four or five to one. Thus, three reference meters of different sizes are usually required to cover adequately a typical range of 1 to 100 gpm and provide overlapping check points among the different flowmeters.

In preparation for a calibration, the reference flowmeter is filled with the test liquid for at least an overnight period and operated for several hours at various flow rates within its range. This is to assure that components such as bearings, gaskets, seals, and floats will attain their regular operating configuration prior to actual calibration. Also, this preparatory operation usually eliminates gum or varnish deposits which may have formed, especially if the meter is received in a dry condition.

For calibration, weight values are selected to give timing intervals of 60 to 90 sec or more at each flowrate to be investigated. The liquid temperature is adjusted to within 1 °F, and the liquid density and viscosity are measured. Five successive weight-time observations are made at each selected test point the first day. On the second day, 5 runs identical with the first series, except that the test points are approached from the opposite direction, are performed, making a total of 10 runs in 2 days. Thus, an indication of the meter hysteresis and stability is obtained. Generally the standard deviation of the 10 separate observations does not exceed 0.08 percent; most frequently it is within 0.05 percent. However, these values are naturally influenced by the type of reference meter and the resolution of its readout or scale.

Recording of Results

The data recorded during the calibration include liquid properties and temperature at the meter, weight of liquid collected, time expressed in milliseconds required to collect this weight, and the meter indication. Other data, such as total pulses occurring during the collection of the selected weight when turbine meters are being calibrated, are also measured and recorded if applicable.

As noted above, a weight-time procedure is used in performing the calibration. The results are expressed finally in gravimetric units after the application of a small correction to compensate for the buoyancy of the air.

However, the majority of liquid flowmeters measure volume rather than mass flow and thus give results expressed in volumetric units. Therefore, when one of these flowmeters is calibrated, the specific weight of the test liquid in the calibrating flowmeter must be determined with a precision adequate to allow accurate conversion from the gravimetric units observed to volumetric units.

This specific weight can be arrived at conveniently to an accuracy of about 0.05 percent using calibrated, soft-glass, 60/60 °F specific gravity hydrometers² with smallest scale division of 0.0005 in accordance with the techniques described by Hidnert and Peffer.³ The temperature at which the specific gravity observation is made should be determined to an accuracy of 0.5 °F. The observations of specific gravity and temperature are converted to specific weight, lb/gal, at the temperature of the test through the use of petroleum measurement tables of the American Society for Testing Materials.⁴

The pycnometer method³ is used when a more precise value of specific weight is required. It is generally accurate to about five significant figures. Under this method density determinations are made at three temperatures covering the range of interest. A graph of the results will then give density at any desired temperature within the observed range. The practical disadvantages of this method are the precision laboratory equipment involved and the inconvenience and time required to perform a density determination as compared to the time for a determination by the hydrometer method.

Reports on Calibrations

The results of calibrations are summarized in one- or two-page reports which include a brief description of the test conditions. An example of the reports was one made this year on two turbine-type flowmeters submitted by an aircraft engine manufacturer. The report stated that these meters had been calibrated by counting the total pulses occurring during collection of a known volume of liquid as measured in a weigh tank and converted to gallons. The meters, with their respective tube assemblies containing flow straighteners, were mounted in a horizontal position with the magnetic pickup coils pointing upward. The temperature of the test liquid was maintained at $85 \pm 1^{\circ}\text{F}$. Results for each of five different frequencies were reported in cycles per gallon.

In another instance, an orifice flowmeter was calibrated with the use of radius taps, with 0.100-, 0.200-, 0.300-, and 0.400-in.-diam orifice plates installed. The calibration was accomplished by measuring the time required to collect selected weights of liquids at six different differential pressure settings for each orifice

plate. The meter was installed with a 3/4-in.-diam flow straightener containing a bundle of straightening tubes connected directly upstream. The temperature of the test was within the range 80 to 85°F , and the specific weights of the liquid at the meter temperature existing during the run were used in calculating the orifice coefficients. The tabulated values of the orifice coefficients were the average of three or more separate observations, and it is believed they were in error by no more than approximately 0.1 percent for the particular flow conditions existing at the time the calibration was performed.

Experience has demonstrated that many of the reference flowmeters repeat to within about 0.1 percent over several years, provided they are not abused nor subject to excessive wear. However, it also has been found that questionable and erratic operation can result when the meter has been abused, or when insufficient care has been exercised in duplicating the liquid properties, entrance flow pattern, and meter position. Because of these variable factors, the Bureau's policy has been not to certify performance of the flowmeters.

It may be possible to arrive at some increased accuracy in the calibration procedure. However, the more promising outlook for the near future seems to be in development of more precise flowmeters. The new turbine type provides a recent example of increase in the precision and convenience of measurement.

¹Liquid flowmeter calibration techniques, by Shafer and Ruegg, *Trans. ASME* **80**, No. 7, pp. 1360-1379 (Oct. 1958).

²Specific gravity 60/60 °F is defined as the ratio of the density of the liquid at 60 °F to the density of water at the same temperature.

³Density of solids and liquids, by Hidnert and Peffer, NBS Circ. 487 (Mar. 15, 1950).

⁴ASTM-IP petroleum measurement tables, American edition, ASTM designation D 1250 (1952).

Certification of Reference Fuel Gas

Transferred to Gas Industry

in 1953 and was developed in cooperation with the Bureau and the Washington Gas Light Company of the District of Columbia during the period 1953-57. The service provided by the Bureau was the result of a continuing need for certified samples of a calibrant gas having a heating value close to that of natural gas. The value of the program is indicated by the fact that 118 companies have thus far purchased 363 cylinders of certified gas.

The evolution of this project is an excellent example of a cooperative effort on the part of an industrial organization and government to develop improved standards for an industry. The action to transfer the certification of the secondary standards to a private institution is in keeping with the special responsibilities of government and industry and is consistent with the established practice of discontinuing certain Bureau services which can be provided by other qualified laboratories.

The program on gas certification was initiated by the Research Department of the American Gas Association

NEW UNIFIED SCALE ADOPTED FOR ATOMIC WEIGHTS

THE International Union of Pure and Applied Chemistry has adopted a new basis for the expression of atomic weights—the exact number 12 as the assigned atomic (nuclidic) mass of the principal isotope of carbon—carbon 12. This action, taken in August 1961, parallels the 1960 action of the International Union of Pure and Applied Physics, and eliminates the confusing difference that has existed between the atomic weights used by chemists and physicists.

Prior to about 1930, both physicists and chemists had used natural oxygen with an atomic weight of 16 as the basis for fixing the scale of atomic weights. However, the discovery that natural oxygen is a mixture of three isotopes, and a slightly variable mixture at that, led physicists to assign the number 16 as the atomic mass of oxygen isotope 16, whereas chemists continued to use 16 as the atomic weight of natural oxygen.

This dual basis, of course, led to two tables of atomic weights, differing by some 275 parts per million (ppm). In addition, such constants as the faraday, Avogadro's number, and the gas-law constant had different values, depending on which basis was chosen. Understandably, considerable confusion resulted from this situation. Values quoted in the literature were often misleading if the scale upon which they were

based was not identified. And it was inconvenient for scientists to constantly make the required conversions.

The situation was further compounded by the fact that even though physicists were using oxygen isotope 16 as the defined reference species, mass spectroscopists had found it far more convenient to use carbon 12 as a working standard, as this atom provides a series of reference points in mass spectrograms. This made it necessary from time to time to redetermine the atomic weight (nuclidic mass) of carbon 12 in terms of oxygen 16.

The International Commission on Atomic Weights took the first step towards unification in 1957 with the proposal that carbon 12 be adopted as a common reference species. Dr. Edward Wichers, Associate Director of the Bureau, who was then President of the Commission, advocated the adoption of the new basis among chemists. Similar work was done among physicists by Dr. J. Mattauch, the leading figure in Germany in the field of mass spectroscopy. After considerable discussion by the organizations concerned, and by interested scientists, carbon 12, the most abundant natural isotope of carbon, was adopted as the reference species for a unified scale, with assigned mass of 12 exactly.

IUPAC table of international atomic weights—1961*

[Based on nuclidic mass of C¹²=12]

Element	Symbol	Atomic No.	Atomic weight	Element	Symbol	Atomic No.	Atomic weight	Element	Symbol	Atomic No.	Atomic weight
Actinium	Ac	89		Gold	Au	79	196.967	Praseodymium	Pr	59	140.907
Aluminum	Al	13	26.9815	Hafnium	Hf	72	178.49	Promethium	Pm	61	
Americanium	Am	95		Helium	He	2	4.0026	Protactinium	Pa	91	
Antimony	Sb	51	121.75	Holmium	Ho	67	164.930	Radium	Ra	88	
Argon	Ar	18	39.948	Hydrogen	H	1	~ 1.00797	Radon	Rn	86	
Arsenic	As	33	74.9216	Indium	In	49	114.82	Rhenium	Re	75	186.2
Astatine	At	85		Iodine	I	53	126.9044	Rhodium	Rh	45	102.905
Barium	Ba	56	137.34	Iridium	Ir	77	192.2	Rubidium	Rb	37	85.47
Berkelium	Bk	97		Iron	Fe	26	b 55.847	Ruthenium	Ru	44	101.07
Beryllium	Be	4	9.0122	Krypton	Kr	36	83.80	Samarium	Sm	62	150.35
Bismuth	Bi	83	208.980	Lanthanum	La	57	138.91	Scandium	Sc	21	44.956
Boron	B	5	a 10.811	Lead	Pb	82	207.19	Selenium	Se	34	78.96
Bromine	Br	35	b 79.909	Lithium	Li	3	6.939	Silicon	Si	14	* 28.086
Cadmium	Cd	48	112.40	Lutetium	Lu	71	174.97	Silver	Ag	47	b 107.870
Calcium	Ca	20	40.08	Magnesium	Mg	12	24.312	Sodium	Na	11	22.9808
Californium	Cf	98		Manganese	Mn	25	54.9380	Strontium	Sr	38	87.62
Carbon	C	6	a 12.01115	Mendelevium	Md	101		Sulfur	S	16	* 32.064
Cerium	Ce	58	140.12	Mercury	Hg	80	200.59	Tantalum	Ta	73	180.948
Cesium	Cs	55	132.905	Molybdenum	Mo	42	95.94	Technetium	Tc	43	
Chlorine	Cl	17	b 35.453	Neodymium	Nd	60	144.24	Tellurium	Te	52	127.60
Chromium	Cr	24	b 51.906	Neon	Ne	10	20.183	Terbium	Tb	65	158.924
Cobalt	Co	27	58.9332	Neptunium	Np	93		Thallium	Tl	81	204.37
Copper	Cu	29	63.54	Nickel	Ni	28	58.71	Thorium	Th	90	232.038
Curium	Cm	96		Niobium	Nb	41	92.906	Thulium	Tm	69	168.934
Dysprosium	Dy	66	162.50	Nitrogen	N	7	14.0067	Tin	Sn	50	118.69
Einsteinium	Es	99		Nobelium	No	102		Titanium	Ti	22	47.90
Erbium	Er	68	167.26	Osmium	Os	76	190.2	Tungsten	W	74	183.85
Euroium	Eu	63	151.98	Oxygen	O	8	a 15.9994	Uranium	U	92	238.03
Fermium	Fm	100		Palladium	Pd	46	106.4	Vanadium	V	23	50.942
Fluorine	F	9	18.9984	Phosphorus	P	15	30.9738	Xenon	Xe	54	131.30
Francium	Fr	87		Platinum	Pt	78	195.09	Ytterbium	Yb	70	173.04
Gadolinium	Gd	64	157.25	Plutonium	Pu	94		Yttrium	Y	39	88.905
Gallium	Ga	31	69.72	Polonium	Po	84		Zinc	Zn	30	65.37
Germanium	Ge	32	72.59	Potassium	K	19	39.102	Zirconium	Zr	40	91.22

* Table courtesy IUPAC and Butterworth Scientific Publications.

^a The atomic weight varies because of natural variations in the isotopic composition of the element. The observed ranges are boron, ±0.003; carbon, ±0.00005; hydrogen, ±0.00001; oxygen, ±0.0001; silicon, ±0.001; sulfur, ±0.003.

^b The atomic weight is believed to have an experimental uncertainty of the following magnitude: bromine, ±0.002; chlorine, ±0.001; chromium, ±0.001; iron, ±0.003; silver, ±0.003. For other elements the last digit given is believed to be reliable to ±0.5.

A revised table of atomic weights, based upon the new standard, was published by the IUPAC in October 1961, with the recommendation that it be placed in universal use as of January 1, 1962. Values in this table differ from those based on natural oxygen by about 40 ppm, and from those based on isotopic oxygen 16 by about 300 ppm. In addition to these systematic changes, many values were revised in light of the re-evaluation of experimental data by the Commission. No atomic weights are listed in the new table for most radioactive elements, as these elements have no fixed value. However, a more complete table, listing the mode of disintegration and mass numbers of selected isotopes, will be published with the proceedings of the 1961 IUPAC meeting.

Whereas chemists have had, since about 1900, the advantage of a table of "best values" for atomic weights, physicists have not until recently had any similar compilation of the masses of individual nuclidian species. Data concerning these constants have been derived either from mass spectrometric measurements

or from "q-values," the net energy changes accompanying nuclear reactions. Differences larger than the estimated experimental uncertainties of each type of data existed between values derived by the two different techniques.

In recognition of this undesirable situation the International Union of Pure and Applied Physics created in 1960 a Commission on Nuclidian Masses whose function will be to evaluate all experimental evidence and to recommend "best values" of nuclidian masses. In anticipation of the work of this official group Everling, König, and Mattauch have published a table of "Relative Nuclidian Masses."¹ Data from this table were used in revising the table of atomic weights. Thus, because chemists and physicists now use the same scale, the "atomic weights" of some 20 mononuclidian elements are identical with the "nuclidian masses" of the nuclides that constitute the elements as they exist in nature.

¹ Relative nuclidian masses, by F. Everling, L. A. König, and J. H. E. Mattauch, *Nuc. Phys.* **18**, 529 (1960).

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Vol. **46**, No. 1, Jan. 1962. 15 cents. Annual subscriptions: \$1.50, 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis. *Basic Radio Propagation Predictions* for April 1962. Three months in advance. CRPL-209, issued Jan. 1962. 15 cents. Annual subscription: \$1.50, 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards
Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, \$4; foreign, \$4.75.
Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, \$2.25; foreign, \$2.75.
Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, \$2.25; foreign, \$2.75.
Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, \$4; foreign, \$4.75.

Current Issues of the Journal of Research

Section A. Physics and Chemistry, Vol. **66A**, No. 1, Jan.-Feb. 1962.
Absolute isotopic abundance of terrestrial silver. W. R. Shields, E. L. Garner, and V. H. Dibeler.
Temperature of a copper arc. C. H. Corliss.
Melting process and the equilibrium melting temperature of polychlorotrifluoroethylene. J. D. Hoffman and J. J. Weeks.
Tritium-labeled compounds VIII. Confirmation of the position of the tritium in D-glucose-6-t and D-glucitol-5-t. L. T. Sniegowski and H. S. Isbell.
Infrared absorption spectra in the study of mutarotational equilibria of monosaccharides. R. S. Tipson and H. S. Isbell.
Preparation of high purity trimethylborane. G. S. Ross, D. Enagonio, C. A. Hewitt, and A. R. Glasgow.
Reaction of several aminopyrimidines with formaldehyde. G. L. McLeod.
Acidic dissociation constant and related thermodynamic quantities for diethanolammonium ion in water from 0 to 50 °C. V. E. Bower, R. A. Robinson, and R. G. Bates.
Fiber structure-property relationships II: Macroscopic deformations of alkylene sulfide crosslinked polycaprolactam fibers. S. D. Bruck.
Ion transport across membranes: I. Definitions of membrane electromotive forces and of flows of electrolytic solutes. B. C. Duncan.

Section D. Radio Propagation, Vol. **66D**, No. 1, Jan.-Feb. 1962.

A survey of the very wide band and frequency independent antennas—1945 to the present. J. D. Dyson.

Numerical investigation of the equivalent impedance of a wire grid parallel to the interface between two media. T. Larsen.

Current on and input impedance of a cylindrical antenna. Y. M. Chen and J. B. Keller.

Radar corner reflectors for linear or circular polarization. G. Latmiral and A. Sposito.

On the theory of wave propagation through a concentrically stratified troposphere with a smooth profile. H. Bremmer.
On the propagation of VLF and ELF radio waves when the ionosphere is not sharply bounded. J. R. Wait.

Fields of electric dipoles in sea water—the earth-atmosphere-ionosphere problem. W. L. Anderson.

Reflection of electromagnetic waves from thin ionized gaseous layers. F. H. Northover.

Reflection and transmission of radio waves at a continuously stratified plasma with arbitrary magnetic induction. J. R. Johler and J. D. Harper, Jr.

On the diffraction of spherical radio waves by a finitely conducting spherical earth. L. C. Walters and J. R. Johler.

An approximate full wave solution for low frequency electromagnetic waves in an unbounded magneto-ionic medium. W. C. Hoffman.

VHF radio propagation data for the Cedar Rapids-Sterling, Anchorage-Barrow, and Fargo-Churchill test paths, April 1951 through June 1958. G. R. Sugar and K. W. Sullivan.

Nonperiodical

Research highlights of the National Bureau of Standards, Annual Report, fiscal year 1961. NBS Misc. Publ. 242 (Dec. 1961) 75 cents.

Publications for which a price is indicated (except for Technical Notes) are available only from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the author.

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OFFICIAL BUSINESS

ADVISORS TO NBS



A joint meeting of key advisors to NBS was held at the Bureau on December 15, 1961. Members of the NBS Statutory Visiting Committee met with representatives of the eighteen divisional Advisory Panels operated by the National Academy of Sciences-National Research Council. The meeting provided an opportunity for members of the Visiting Committee to hear reports from the NAS-NRC panels and for discussion of means for coordinating activities of the various groups which advise the Bureau.

Seated at the table, clockwise from the extreme left are: Prof. A. A. Oliner, Polytechnic Institute of Brooklyn, Chairman, Radio Standards Panel; Dr. T. I. Taylor, Columbia University, Chairman, Analytical and Inorganic Chemistry Panel; Dr. J. H. Dillon, Textile Research Institute, Chairman, American Institute of Physics Delegation; Dr. A. J. Phillips, American Smelting & Refining Company, Metallurgy Panel; Prof. C. H. Townes, Massachusetts Institute of Technology, Statutory Visiting Committee; Dr. A. V. Astin, NBS Director; Dr. M. J. Kelly, Chairman, Statutory Visiting Committee; Prof. R. H. Dicke, Princeton University, Chairman, Atomic Physics Panel; Dr. P. C. Cross, Mellon Institute, Physical Chemistry Panel; Prof. A. H. Waynick, Pennsylvania State University, Chairman, Central Radio Propagation Laboratory Panel; Dr. W. C. Hansen, Consulting Chemist, Chairman, Building Research Panel; Mr. H. M. Parker, Hanford Laboratories, Chairman, Radiation Physics Panel.

Standing, left to right: Dr. J. T. Lusignan, Ohio Brass Company, Electricity Panel; Dr. A. T. McPherson, NBS Associate Director and Chairman, NBS Advisory Committee on Engineering and Related Standards; Prof. P. W. Selwood, Northwestern University, Chairman, Mineral Products Panel; Dr. C. G. Overberger, Polytechnic Institute of Brooklyn, Chairman, Organic and Fibrous Materials Panel; Dr. C. McKinley, Air Products, Inc., Chairman, Cryogenic Engineering Panel; Dr. S. R. Beitler, Ohio State University, Chairman, Mechanics Panel; Mr. R. W. Larson, General Electric Research Laboratories, Chairman, Instrumentation Panel; Dr. I. C. Schoonover, NBS Associate Director; Mr. R. S. Walleigh, NBS Associate Director; Prof. J. E. Mayer, University of California, Chairman, Heat Panel; Dr. P. D. Foote, Executive Secretary, NAS-NRC Panels; Dr. R. D. Huntoon, NBS Deputy Director; Mr. W. A. Wildhack, NBS Associate Director and Chairman, NBS Advisory Panel on Calibration and Measurement Services.

Also in attendance, but not in the photograph were: Prof. M. Rubinoff, University of Pennsylvania, Data Processing Systems Panel; Dr. E. Wichers, NBS Associate Director; and Mr. W. S. Bussey, Assistant to NBS Director and Chairman, NBS Weights and Measures Advisory Committee. Representatives of the Advisory Panels for the Metrology and Applied Mathematics Divisions of the Bureau were unable to attend as were other members of the Statutory Visiting Committee, Prof. F. Seitz, Univ. of Illinois; Dr. L. V. Berkner, Pres., Graduate Research Center, Inc.; and Dr. C. H. Greenewalt, Pres., E. I. du Pont de Nemours & Co.

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